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PROGRESS IN CACAO RESEARCH.

THE Ninth Annual Report on Cacao Research, which comprises the results of botanical, chemical and ecological investigations carried out during the past year, merits the attention of all who are concerned with cacao, whether from the scientific or practical viewpoint. Although one or two of the papers included in the Report will be of more interest to scientific workers than to cacao planters, the Report as a whole is practical in scope including as it does articles on factors controlling the yield of young cacao, agents of pollination in cacao, manurial experiments on cacao and physiological studies with reference to cherelle wilt. With the severe decline in cacao production in Trinidad since 1930, investigations which seek some of the many factors responsible for this decrease in yield, or experiments designed to offset the decline, are of paramount importance. This is particularly the case at present when every effort is being made to increase the crop, and the question arises as to how this can best be achieved, or to what reasons failure to produce a normal or increased yield can be ascribed.

The Botanical Section of the Report opens with an article (which is reprinted in this issue of *Tropical Agriculture*) on "The Cost of Cacao Propagation by Cuttings". As the method of propagation of plants by cuttings is becoming increasingly important and promises to be the standard one to be used in the provision of high yielding plants for the cacao rehabilitation scheme, the article will be of value to all who are considering the propagation of cacao by this method.

The number of factors which determine the yield of cacao is considerable. This means the initiation of a correspondingly large number of investigations, some of a long range nature, but all essentially practical if, finally, they lead to an understanding of those conditions, favourable or otherwise, which influence the tree and control the yield of fruit. Investigations of this type are well illustrated by the work which is being carried out on some factors controlling the yield of young cacao. The paper describing this work is the third of a series on the same subject which indicates that in this case the investigations are of a long range nature. That the expected increase in crop of the young cacao trees under observation failed to materialise is ascribed in this instance to unfavourable weather conditions which resulted in increased wilting of the pods. Thus one factor, at least, which has a bearing

on the yield of cacao is established, and although, in this case, it is one that cannot be controlled, nevertheless it contributes to the clarification of the problem of the factors involved in the analysis of fruitfulness.

Another factor contributing to yield is the rôle played by pollinating agents, and a detailed study carried out over a period of fourteen months has disclosed an interesting statistical correlation between setting and the density of red ants and thrips in the flowers. Although this result does not prove that these insects are agents of pollination, the observations should certainly be useful to those engaged in the search for the pollinating agents of cacao, and may help to establish a method whereby yields may be increased.

The Chemical and Ecological Section of the Report deals mainly with the results of manurial experiments on cacao in Trinidad, and studies in the physiology of *Theobroma cacao*, with special reference to cherelle wilt. The practical nature of these investigations, especially as regards their bearing on increased crop production, cannot be questioned if one considers (*a*) that successful manuring depends on a thorough knowledge of local soil conditions, and (*b*) that failure of cacao pods to reach maturity largely decides the magnitude of the crop, for the loss of pods through wilt may vary from 20 to over 90 per cent. of the number of pods that are set. Thus, one series of investigations seeks to discover how crop production may be increased by direct methods, whilst the other seeks the causes underlying crop failure. In either case, the final result will be same, *viz.*: increased yields, provided the work is attended with success, and this indeed seems assured, for some factors have already been brought to light that have an important controlling influence on the fruitfulness of the tree. As an example, experimental evidence is adduced in support of the theory that wilt is primarily due to nutrient and water deficiency, that during the development of the cacao pod potassium is the element most in demand, and that the development of a leaf-flush may cause a marked withdrawal of mineral elements out of mature leaves comprising a previous flush. A similar withdrawal may even affect the developing pod, and may thus be a contributory cause of wilt. Other factors on which yield is dependent are contained in Dr. Pound's main findings and conclusions, deduced from his manurial experiments, which are summarised in the Report.

The manurial experiments described are intimately connected with investigations of the cacao soils of Trinidad which have been carried out intermittently at the College since October 1928 with the objects (*a*) of gaining information on the fertility (nutrient status) of the soils, chiefly for the purpose of advising treatments for manurial experiments; (*b*) of discovering the chief features that distinguish "good" cacao soils from "bad"; (*c*) of describing and delineating the distribution of different production categories of the cacao soils to facilitate economic researches into the Island's cacao industry; and (*d*) of providing data for the comparative study of the cacao soils of other regions, such as West Africa.

These soil investigations have been of an essentially practical nature and, with the recent attempt that has been made to classify the soils and to plot their distribution by means of a Reconnaissance Soil Map and a Tentative Land Productivity Map, a more complete co-ordination and understanding (the natural outcome of the combined results of closely related investigations) is being established regarding soil conditions most suitable for cacao production.

The work described in the Annual Report well indicates the lines of approach and the efforts that are being made to offset the adverse factors that have so recently set in with such disastrous results to the cacao crop. Only through an understanding of the botany of the tree, its response to manurial and other treatments, and the ecological conditions connected with its development, can those factors which are adverse to productivity (many of them not existent 20 years ago) be understood and offset. The co-ordination between all the branches of the work is well marked, and the results that have already accrued and continue to accrue indicate that some success has already been achieved, and that further significant advances can confidently be expected. These will yield results and practical information not only of value to the local industry but to the cacao industries of colonies other than Trinidad.

BACTERIOPHAGE AND PLANT LYSINS.

THE origin of the mysterious bacteriophage, the transmissible agent which dissolves living bacteria, has never been accounted for. It was discovered by Twort and arises spontaneously in cultures of bacteria under certain conditions. D'Herelle maintains that it is a living ultra-microscopic agent, others believe that it is a chemical agent, capable of regeneration, analogous to a plant virus. In a paper communicated to the American Association for the Advancement of Science at Columbus, Ohio, in December last, Roy C. Thomas suggests a possible mode of origin. He finds that a non-specific lysin or 'dissolving' agent is found in many plants. It is inactivated by heating to 56°C. for thirty minutes, and has much the same action upon bacteria that bacteriophage has. When this lysin comes into contact with bacteria susceptible to its action, a change occurs resulting in the formation of a transmissible lytic principle similar to bacteriophage; it is not inactivated at 60° and only partially at 65°. It is suggested that this is the origin of the bacteriophage, at least in plants. With regard to corn wilt bacteria, with which much work was done, a bacteriophage can be obtained for any strain which does not contain one, and a phage developed for a culture is highly specific for it.—(*Nature*, Vol. 145, No. 3673, p. 468, 1940.)

THE COST OF CACAO PROPAGATION.

By E. E. Cheesman and G. E. L. Spencer.

The propagation of cacao by cuttings, whilst still regarded as an experimental process, has now passed from one phase of research to another. The technique is established, and young trees raised from cuttings are in bearing.

Their performance, so far, is very promising. There are still only a few of them old enough to give useful records, since the first large planting at River Estate was rather late in 1937. There are, however, 51 three year old trees on San Juan Estate which have been recorded through the 1939-40 crop by the College Department of Economics. Of these, 41 are in bearing, and gave during the year 68.6 lb. of cacao, an average of 1.3 lb. per picket. The 51 trees belong to 11 different clones—some represented by only a single tree—and some of them seem to be relatively slow in coming into bearing. The figures for the four clones making up the bulk of this planting are:—

Clone.	Pickets.	Bearing trees.	Total yield. (lb.)	Average per picket.
I.C.S. 1	15	13	30.2	2.0
4	8	6	12.4	1.5
22	8	7	5.9	0.7
45	6	5	9.6	1.6
Total ...	37	31	58.1	1.6

These trees are growing in a replanted field on chocolate soil, which is one of the best cacao soils in Trinidad, and they have had every care from the time of planting. Similar yields are not to be expected from "cuttings" planted on the poorer soils or neglected after planting; nor is the bearing likely to be quite so early where the trees are used as "supplies". With these reservations, the figures still show that the new method has potentialities, and is well worth further study.

In the translation of any new technique into practical agricultural or horticultural procedure, there is inevitably a rather long "experimental" period during which a careful watch must be kept for the development of unsuspected defects or disadvantages. In this period the practical agriculturist or horticulturist, rather than the agricultural scientist, must be the chief experimenter. It is necessary that the new technique shall be tried out under a variety of commercial conditions, and on a scale large enough to be profitable if it succeeds, yet not so large as to be ruinous if it should happen to fail. The scientist may advise and help, but commercial growers must carry out the work for themselves before they can decide whether it really is profitable.

Thus for more than a decade budded rubber was tested on a commercial scale in the East, cautiously, but with gradually increasing confidence. We may hope that the history of vegetatively propagated cacao in the next decade will be similar.

Adequate testing will involve the planting of many thousands of vegetatively propagated trees, and it becomes important to estimate the cost of rooting cuttings on a commercial scale.

Our own experiences with the I.C.T.A. propagating plant have not been exactly on a commercial scale, but in the six months from 1st July to 31st December, 1939 we kept records of output and labour requirements from which a rough estimate can be calculated. In this period there was enough material to keep the equipment working at full capacity, and after culling out weaklings we took from it 1,870 good plantable young trees. This was "wet season" propagation, and there is usually some drop in the drier half of the year, but 1939 was a year of low rainfall and the rooting percentage was not up to the usual level. The capacity of the plant in a full normal year may therefore be placed conservatively at 3,600, or 1,200 from each of the three "batteries" of propagating bins in use. In a favourable year, or in a district more suitable for cacao nurseries than St. Augustine, the output might easily reach 1,500 per battery, but our calculations are based on the 1,200.

Our observations on labour suggest that if we had not much other horticultural work proceeding at the same time our plant would be too small for economical working. A more economical and convenient unit would be one of twice the capacity, and our estimates are therefore drawn up for the larger output.

Equipment.

A plant with a capacity of 7,000 to 9,000 rooted cuttings a year would consist of six banks or "batteries" each of 12 glass-lidded propagating bins, as described and illustrated in the Fifth Annual Report (and in *Tropical Agriculture*, 13 (1936), 201). For commercial use the division into compartments, useful for experimental work, could be omitted. Further requirements would be four batteries of similar size, but with lower walls and calico-covered lids, used for "hardening" the cuttings after potting; a concrete floor of about 1,800 square feet, covered with a roof, half glass and half galvanized iron; and about half an acre of nursery from which the cuttings would be obtained.

The equipment described is somewhat expensive. Its actual cost must vary with district, with the materials used in construction of the roof, and

with the " finish " of the work, but a fair general estimate in Trinidad seems to be about $3,000, excluding the cost of land occupied. If this sum is written off in ten years (which is a great deal less than the life of the structure), or in other words spread over the first 75,000 cuttings, it amounts to four cents per plant.

Materials, &c.

Apart from capital outlay and labour, expense is incurred for :

1. Calico for overhead canopies and curtains, which at ten cents a yard needs renewing about once a year.
2. Cheesecloth for covering lids.
3. Sand for the bins—virtually a capital charge as there is very little wastage.
4. Chemical preparations used for stimulating rooting.
5. Potting compost.
6. Planting baskets—three cents each.
7. Repairs to propagator lids, replacement of broken glass and rotten woodwork, painting, &c.

For some of these items it is impossible to give any estimate of general applicability—the cost of sand, for example, depends almost entirely on the length of haulage. Our own costs for materials work out at 6⅔ cents, including baskets, but although this covers the chief items it ignores compost, which we found impossible to assess accurately, and repairs, which did not happen to be necessary during the period of our observations. We consider that a round figure of ten cents per cutting, including the basket, is fair.

Labour.

An equipment of six batteries has been chosen as a unit for calculation, because this should be workable by one relatively highly-paid propagator with one labouring assistant. The propagator should be able to do all the setting of cuttings, watering, and " potting " into baskets, by arranging the work on a systematic basis of so many bins emptied and refilled each day. The labourer would look after the nursery and prepare potting compost, and be available for watering in the absence of the propagator. It is to be remembered that watering has to be kept up seven days a week. Rates for suitable reliable men will vary with district. Our own labour costs on the basis adopted are almost exactly six cents per rooted cutting.

Total cost.

The total cost thus comes out at tenpence (20 cents) per cutting, made up of twopence for capital charges on equipment, fivepence for materials, and threepence for labour. We give the figure with all diffidence, admitting that it is based partly on guesswork and partly on local conditions which will not apply everywhere, even within Trinidad. We give it because at the present time many interested planters probably have no idea whether a " cutting " costs a cent or a dollar, and if our figure is only read as " somewhere between 15 cents and 25 cents " it may still add a certain degree of precision to discussions of vegetative propagation.

Comparison with other methods.

Direct comparison with the cost of budding or of raising nursery seedlings to an equivalent plantable stage is difficult, because these operations can be carried out in several different ways on estates, according to conditions. Seedling propagation in an outdoor nursery near to the final planting site involves practically no expense except for labour drawn from the estate force, and budding under similar conditions, though it involves the employment of a more skilled man, costs almost nothing for materials.

We can say, however, that budding carried out in a central nursery away from the planting site costs us, for well-grown experimental planting material, at least as much as propagation by cuttings. The seedling stocks, sown in baskets to avoid disturbance of root systems in transplanting, occupy the covered floor for nearly a year, against the average of three months for cuttings. Thus an equivalent output, though needing no propagator batteries, would need four times the roofed area, putting up capital charges from four cents to six cents. The basket usually rots before the plant is ready for the field, and needs replacement, which largely counterbalances the saving on other materials, and as there are always four times as many plants on hand to be looked after, there is no saving on labour. Our probable costs for buds (estimated on less detailed observations than in the case of cuttings) are : Capital charges on equipment—six cents ; materials—eight cents ; labour—six cents ; total—20 cents.

It is worth noting, too, that an apparent reduction in cost may not prove economical in the end. For example, by growing and budding the rootstocks in the open, the capital charge may be cut out, with apparent saving in a favourable season ; but as soon as unfavourable weather occurs, the extra attention necessary to keep the plants vigorously growing, or the lower percentage of " takes " which will result if they are not kept healthy, soon swallows up the saving. One essential requirement of planting material is that it shall be ready when wanted, and the justification of expenditure on equipment and such materials as planting baskets is that these ensure a steady output, so far as anything in horticulture can be ensured. When this aspect is duly considered, it is probable that even the cheapest form of seedling propagation is not as cheap as it appears to be.

A NOTE ON THE MATURATION PERIOD OF CACAO PODS IN GRENADA.

By St George C. Cooper, Dip. Agric., A.I.C.T.A.
(Agricultural Officer, Grenada Department of Agriculture.)

Introduction.

In the course of an investigation into the incidence of self-incompatibility in part of the Grenada cacao crop, it occurred to the writer to determine the length of the maturation period of the pod from fertilization to ripening. Popular belief in Grenada maintains that the life of a pod is four months from fertilization to harvesting, but there are no statistical data to support that contention.

Cheesman (1) found in Trinidad that the fruit attains its maximum dimensions in about five months and that the month of greatest increment is the fourth after fertilization. Growth slackens in the fifth month and the sixth is spent in maturation. His figures applied to the dry season.

Workers in the Gold Coast and in Nigeria have obtained an increment in size up to the end of six months and maturation in seven months. In the latter Colony, the maturation period varied from four to a little over five months.

II.—The Present Investigation.

Since June 1938, data have been accumulated showing the date of pollination, the monthly growth and date of harvest of the individual pods. Three estates were selected with elevations at 200, 400 and 700 feet respectively. Five trees were labelled on each estate and detailed measurements were started on ten pods per tree. Some of these pods either failed to reach maturity or shrivelled in the early stages of the investigation. Measurements were made as accurately as possible with a measuring tape.

III.—Results.

Out of 150 pods on which the tests were started, only 64 reached maturity and Table I shows the frequency distribution of their harvest periods.

Table I.

Frequency of Distribution of Pods.

Harvest Months ...	4½	5	5½	5¾	6	Over 6
Number of Pods ...	2	18	17	8	12	7

Table II shows the monthly average growth in length together with the average circumferential growth in inches.

Table II.

Average Monthly Growth of Pods.

Time in mths.	1	2	3	4	5	6
Average Length, Ins.	2.38	4.47	6.11	7.86	8.02	8.02
Average Circumference, Ins.	2.33	4.86	7.80	10.35	10.92	10.92

IV.—Discussion.

Reference to Table I shows that the maturation period of the cacao pod in Grenada lies between five and six months. In Table II the growth figures show that full size is reached in the fifth month, a result in accordance with that obtained by Cheesman in Trinidad. The month of greatest increment in Grenada, in the case of growth in length, appears to be the second after fertilization, and for growth in circumference, the third after fertilization.

It is recognized, however, that length and circumference are only convenient indices to the increase in volume of an irregular spheroid. The economic interest lies in the increase in mass.

There has been no evidence so far of season affecting the length of the growth period as seen from the following figures:—

Average maturation period of pods setting in:

March	....	5.50 Months
April	....	5.43 do.
May	....	5.55 do.
June	....	5.87 do.
July	....	5.00 do.
August	....	5.25 do.
November	....	5.50 do.
December	....	5.50 do.

V.—Summary.

1. The average maturation period of cacao pods in Grenada is established at between five and six months.

2. The lack of effect of season on the length of the maturation period is demonstrated.

VI.—Acknowledgments.

I wish to express my grateful thanks to the Hon. E. J. Wortley, C.M.G., Director of Agriculture, for permission to publish this note and to Professor Cheesman for reading the manuscript and for making some useful suggestions.

VII.—Reference.

1. Cheesman, E. E.—Economic Botany of Cacao. *Supplement to Tropical Agriculture*, 1932.

SOME PRELIMINARY STUDIES OF TRANSPIRATION AND CARBON ASSIMILATION IN CACAO.

By D. B. Murray.
(*Department of Botany and Genetics, Imperial College of Tropical Agriculture.*)

Introduction.

Cacao in Trinidad is almost invariably grown under shade, trial and error having shown in the past that it thrives best under semi-forest conditions. It is not known however, in just what way shade conditions produce the optimum environment and knowledge of the general physiology and metabolism of the plant is badly needed as a basis for the explanation of such agricultural practices.

This paper reports preliminary work on the rates of transpiration and carbon assimilation of cacao leaves, both under laboratory conditions and in the field, which is intended as a first step towards obtaining such knowledge. The plants used were young trees, about three years old, from fan cuttings, and were growing in a highly shaded nursery. The work was started in the wet season and carried on into the dry.

Transpiration.

Transpiration was first studied by the cobalt chloride paper method. It was found that the leaf in the field loses water roughly from twice to five times as fast from the lower surface as from the upper, and microscopical examination showed the existence of stomata on the lower surface only.

To obtain more accurate results, water loss from the leaf was next obtained by weighing. A glass leaf chamber was made with inlet and outlet tubes and this was attached to a leaf with a mixture of beeswax and vaseline. Air, dried by passage through concentrated sulphuric acid and a calcium chloride tower, was drawn by means of an aspirator through the leaf chamber and then through two weighed, calcium chloride-filled, U tubes. Dry air passing over the leaf will tend to increase the normal rate of transpiration but only a slow rate of flow of 2-3 litres/hour was used and for comparison purposes both leaf surfaces would be similarly affected. Subsequently, normal air was drawn through at a rather greater rate and the moisture content measured by a control.

Each run lasted for an hour, at the end of which period the U tubes were removed for weighing and a fresh set substituted.

A comparison of the water loss from the upper and lower surfaces under field conditions gave the results below (*see* also Fig. I).

These results confirm what had already been shown by the cobalt chloride paper method, *viz.*: that water loss from the lower surface, where the stomata are situated, ranges from five to ten or even more times the water loss from the upper surface. Water loss from the upper surface is entirely cuticular and, subtracting this amount from the amount lost by the lower surface, will give the amount of water transpired by the stomata alone. Since the cuticular loss remains very nearly constant, the variation in water loss from the lower surface must be to some extent due to stomatal movement.

An attempt was made by F. W. Cope (unpublished communication) to measure stomatal movement by means of the resistance porometer, but absolutely no change in pressure inside the porometer cup could be detected. Microscopical examination of the leaf revealed that the entire mesophyll is composed of non-intercommunicating areas bordered by sclerenchymatous bundles so that in the absence of stomata on the upper leaf surface any air flow through the leaf is impossible, and no porometer measurements are feasible.

Further work on transpiration was carried out in conjunction with photosynthesis and these will be considered in relation to each other.

Carbon Assimilation.

Of the problems involved, Nutman (4) says "Little work has been done on the march of apparent assimilation of plants in general through the day under natural conditions, probably because of the difficulty of devising an apparatus suitable for field use and at the same time sensitive enough to enable the rate of assimilation to be measured over a period of a few minutes. It

Water loss in grms. Area of leaf chambers – 30.6 cm².

Time of day	a.m. 7-8	a.m. 8-9	a.m. 9-10	a.m. 10-11	a.m. 11-12	noon to p.m. 12-1	p.m. 1-2	
Upper surface	.012	.011	.009	.011	.010	.008	.014	
Lower surface	.053	.052	.058	.068	.076	.068	.104	
		Dull			Sunny	Overcast		Rain

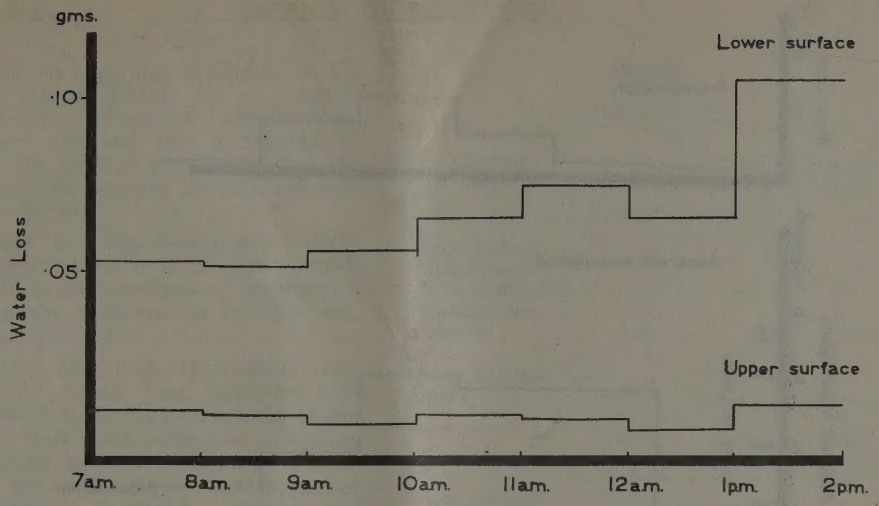
gms.
Lower surface
·10
·05
Water Loss
Upper surface
7am.
8am.
9am.
10am.
11am.
12am.
1pm.
2pm.

FIG. I

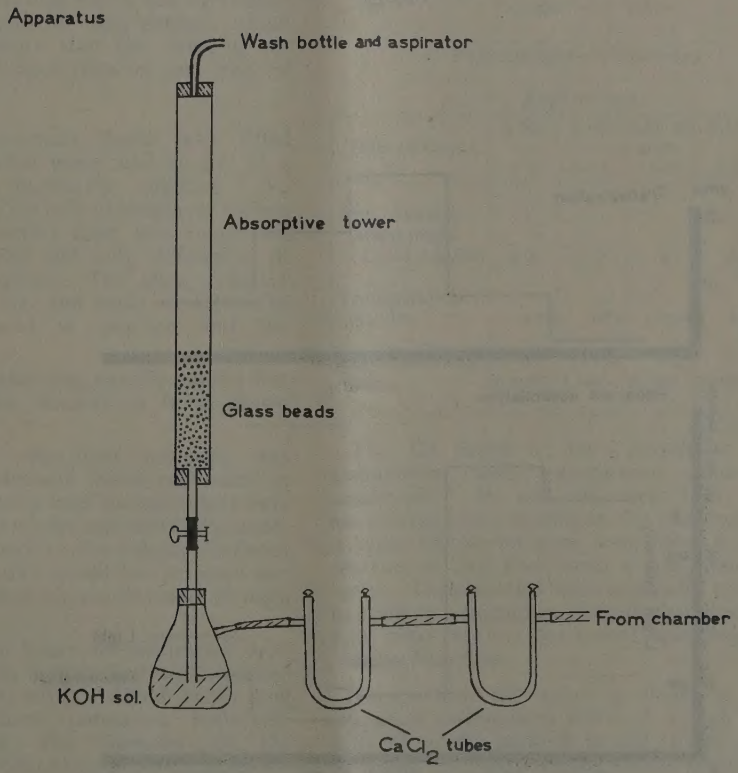
Apparatus
Wash bottle and aspirator
Absorptive tower
Glass beads
From chamber
KOH sol.
CaCl2 tubes

FIG.II

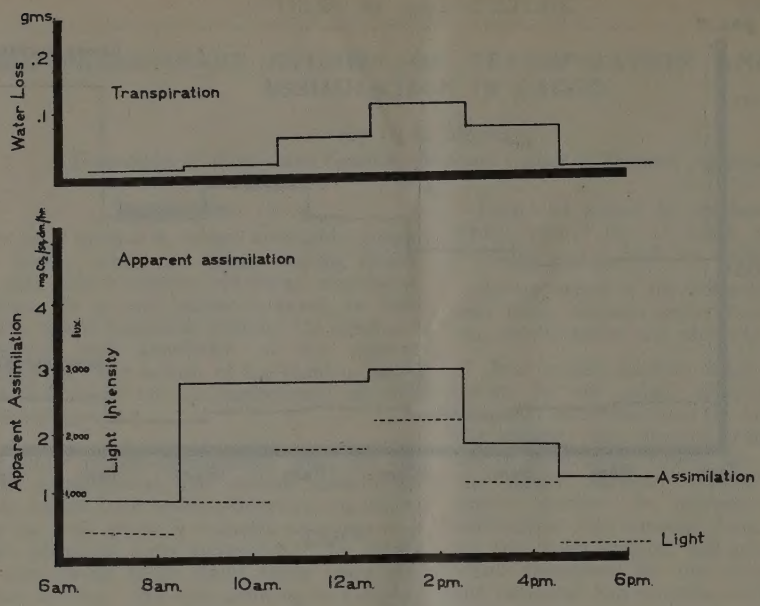

FIG. III

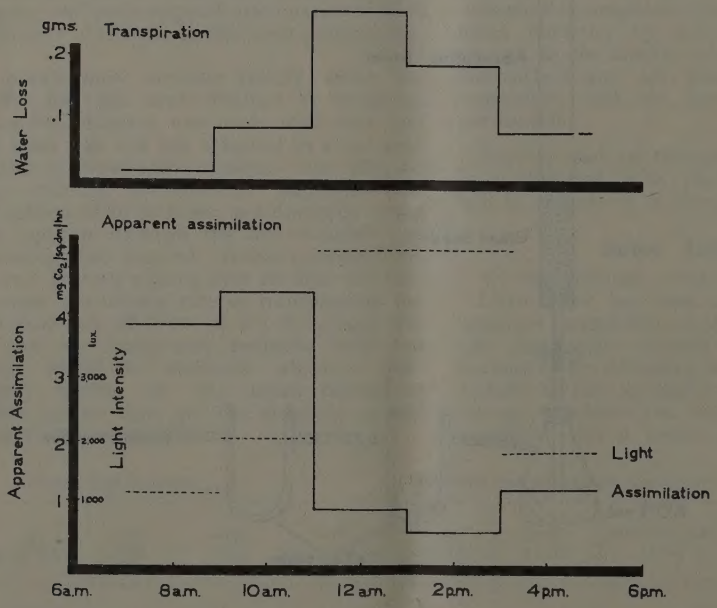

FIG. IV

is apparent that an apparatus depending on the absorption of carbon dioxide by an alkaline solution and the subsequent determination of the amount absorbed has a number of disadvantages, the chief of these being that the result gives only the average assimilation over a considerable period."

While realising these objections it was thought that even determinations over two-hour periods would be useful in this preliminary work and a modification of the apparatus of Heiniche and Hoffman (1) was adopted.

The absorption unit (Fig. II) consists of a glass tower about 60 cm. long, half-filled with glass beads to break up the gas stream and attached to a 500 c.c. flask containing the potassium hydroxide solution used as absorbent. A wash bottle at the top of the tower contains a few drops of potassium hydroxide solution and phenolphthalein and indicates whether all the carbon dioxide in the gas stream is being absorbed. Transpiration can be measured at the same time by the calcium chloride-filled U tubes.

With the aspirators available an air flow of 9 litre/hour was maintained which was equivalent to 0.33 litre/hour/sq.cm. of leaf surface, which was sufficient to ensure that the outgoing air was not deprived of more than 20 per cent. of its carbon dioxide.

Procedure.—The reservoir flasks were filled with 50 c.c. of distilled water and 50 c.c. of a 0.15 N potassium hydroxide solution. No attempt was made to exclude atmospheric carbon dioxide since the control flask was treated in exactly the same way and only differences in absorption were required. The glass chamber was attached to the leaf and made air tight the reservoir flasks placed in position and the aspirators started.

The control apparatus was exactly similar but with no leaf chamber, normal air being drawn through the tower.

Every half hour the light intensity was measured with an exposure meter calibrated in lux. At the end of every hour the aspirators were refilled to the original marks and switched around, so that any discrepancy in the volumes between the 0 and 9 litre marks would be corrected for, and the same amount of air would travel through each apparatus.

At the end of two hours the aspirators were stopped, the potassium hydroxide solution washed down into the flask with distilled water and flasks containing fresh potassium hydroxide solution substituted. The contents of the reservoir flask were washed into a 250 c.c. standard flask and 10 c.c. of a 12 per cent. solution of barium chloride added to precipitate carbonates. The whole was made up with distilled water and allowed to settle. 50 c.c. were withdrawn at a time and titrated with 0.1 N hydrochloric acid using phenolphthalein as an indicator.

Results.

Leaf in Shade.

Time of day.	a.m. 6.30-8.30	a.m. 8.30-10.30	a.m.-p.m. 10.30-12.30
App. Assimilation mgm CO_2/sq.dm./hr.	.91	2.7	2.7
Transpiration gm./hr.	.015	.019	.056
Light Intensity lux	400	800	1,700
	p.m. 12.30-2.30	p.m. 2.30-4.30	p.m. 4.30-6.30
App. Assimilation mgm CO_2/sq.dm./hr.	2.9	1.8	1.3
Transpiration gm./hr.	.101	.067	.005
Light Intensity lux	2,200	1,200	200

Full sunlight—6-8,000 lux.

Leaf in Sun.

Time of day.	a.m. 7-9	a.m. 9-11	a.m to p.m. 11-1	p.m. 1-3	p.m. 3-5
App. Assimilation mgm CO_2/sq.dm./hr.	3.9	4.3	.9	.5	1.3
Transpiration gm./hr.	.016	.081	.259	.186	.076
Light Intensity lux	1,200	2,000	5,000	5,000	1,800

Fig. III shows a day's march of apparent assimilation and transpiration under shade conditions. It will be seen that apparent assimilation rises rapidly in the morning to about 3 mgm CO_2/sq.dm./hour soon after 8 a.m. and remains at this level until 4 p.m. when it falls away. Transpiration rises gradually through the morning to a maximum just after midday and then falls away again. No record was made of the relative humidity.

In the sun, the march is shown in Fig. IV. Apparent assimilation starts at a high level but falls off rapidly between 10 and 11 a.m. and stays at a low level until 3 p.m. when a slight recovery occurs. This recovery was sometimes found to be greater. Transpiration, as compared with that of a leaf in the shade, reaches a maximum far earlier in the day and the water loss then is more than twice that of a shaded leaf. It is impossible to say to what extent insolation

plays a part but experiments with the leaf in a cellophane envelope showed that it may acquire a temperature 3-4°C higher than the surrounding air.

As a check on the average rate of assimilation the dry weight increase was measured by taking 10 punches with a cork borer from the halves of 5 leaves in the morning, and the corresponding halves in the afternoon. This gave an assimilation rate, neglecting translocation, of between 3 and 4 mgm CO_2/sq.dm./hour confirming the fact that cacao belongs to the group of typical tropical sun plants exhibiting very low rates of assimilation compared with temperate region plants.

In comparison with the average of 3-4 mgm CO_2/sq.dm./hour for cacao, Nutman (4) found 2-3 for coffee, and McLean (3) 0.6 for the coconut. These results can be contrasted with temperate region values of from 10 mgm CO_2/sq.dm./hour for the potato (Lundegarth) to 20 mgm CO_2/sq.dm./hour for the apple (Heiniche and Hoffman).

The writer is in agreement with Nutman that "It is regrettable that more data are not available on the assimilation rate of tropical plants under natural conditions."

Conclusions.

This work, though only of a preliminary nature, gives some idea of the intensities of transpiration and carbon assimilation of cacao, and puts it into line with the coconut and coffee among tropical crops in exhibiting a midday drop in assimilation with intense sunlight. This physiological work is an essential to the more complete study of the plant in relation to its environment, which study is indispensable to the understanding of agricultural practices in the production of the crop in question.

Summary.

1. Methods are described for measuring the loss of water and the uptake of CO_2 of attached cacao leaves in the field.

2. Results are given for the transpiration and apparent assimilation of cacao leaves under sun and shade conditions.

3. Transpiration rises to a maximum at midday whereas carbon assimilation rising in the morning falls off at midday with light intensities over $\frac{1}{3}$ of full sunlight.

4. Shade appears to give a better environment for the leaf than full sunlight.

Acknowledgment.

The writer's thanks are due to Professor Cheesman for helpful criticism in the preparation of this paper.

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AN APPRECIATION.

Mr. G. RODRIGUES.

The congratulations of the staff and students of the College are offered to Mr. G. Rodrigues, Senior Analyst of the Chemistry Department, on his recent election to the Fellowship of the Institute of Chemistry of Great Britain and Ireland. This great distinction has been well earned, through his own merit and industry. Mr. Rodrigues joined the College staff in August, 1926, as first Analytical Assistant. Prior to this, he was a student at St. Mary's College, Port-of-Spain, Trinidad, and runner-up for the Island Science Scholarship in 1923. In 1928, Mr. Rodrigues began studying privately in his spare time for the examination for the Associateship of the Institute of Chemistry. In January 1933, he attended the Chelsea Polytechnic Institute in London during a four months' period of leave of absence from the College. At the end of this period, Mr. Rodrigues passed the examinations in Theoretical Chemistry for the Associateship of the Institute of Chemistry and subsequently, in Trinidad, he passed the examinations in Practical Chemistry. He was duly awarded the Associateship early in 1935 on his examination results. Having since satisfied the authorities as to his professional services and activities, Mr. Rodrigues was promoted to the Fellowship in June, 1940.

During the 14 years of his association with the Chemistry Department of the College, Mr. Rodrigues has played an outstanding part in most of the investigations that have been undertaken therein, and his name has appeared as sole or joint author of many papers on various agricultural-chemical topics. He has organised and supervised the analytical section of the Chemistry Department, and has been mainly responsible for the course of instruction in chemical analysis, and has also taught agricultural geology to First Year Students. Latterly, Mr. Rodrigues' chief interest has concerned a detailed study of the genesis of humid tropical soils from different kinds of parent rocks, researches whose successful accomplishment depends on a high order of chemical analytical skill, such as Mr. Rodrigues' natural aptitude and long experience have enabled him to apply to them.

REVIEWS.

THE CONTROL OF WEEDS.

Herbage Publication Series. Bulletin 27, *Imperial Bureau of Pastures and Forage Crops*, Aberystwyth, 1940. Price *7s. 6d.*

This symposium on the control of weeds includes, in 160 pages, articles from Canada, the United States of America, Germany, Australia, New Zealand and South Africa. Some of the countries have contributed one article only: others two or three papers by different authors.

On reading through the papers as a whole, the most striking thing is the fact that in all the newer countries the predominant and most noxious weeds are immigrants. Some species such as Nutgrass and Wild Oats, are indeed world pests. It is staggering to think of what would have been saved if the spread of such pests about the world could have been prevented.

It is an interesting comment on the backward state of the world's knowledge of weeds and their control that it is not difficult to find substantially contradictory statements in the different articles in this symposium. For instance, on page 24 in the Canadian article it is stated that "the killing efficiency of a chemical depends entirely upon its ability to sterilize the top soil for a long time, and not upon its ability to circulate through the plant's system, a claim that is sometimes made by commercial agents selling chemical weedkillers". Conversely on page 44, in one of the articles from America, one finds the statement "and the sap from these, being freed from osmotic forces, is drawn rapidly down into the roots. If the spray solution contains a toxic substance, such as arsenic, that can move freely through killed plant tissues, this substance will diffuse into the cells, become incorporated in the sap, and eventually be carried in the backward-flowing stream".

Most of the papers deal mainly with one or other of the methods of control—chemical, biological or cultural. The subject of the chemical control of weeds is one in which progress is being made so rapidly at present that information two years old is out-of-date, and it is the up-to-dateness of the papers covering this subject, especially that from America, which renders them particularly valuable. The papers on the biological control of weeds from Australia and New Zealand are perhaps more interesting than directly useful to workers in other parts of the world, as the conditions which have led to the striking successes with such measures in those countries are seldom paralleled elsewhere. The papers of the greatest general interest are those dealing with control by cultural means, and especially that which was contributed from Canada by T. K. Pavlychenko, of which a summary appears in this number of *Tropical Agriculture*.

A point that emerges from a perusal of several of the papers is the growing recognition among agricultural experimenters of the fact (already generally, though perhaps, often tacitly, recognized by the most practical farmers) that a most important reason for rotating crops is that rotation is the cheapest way of keeping weeds under control; and that this effect of rotation is not merely due to the inclusion of periodical "cleaning crops".

The article contributed from Canada contains the results of some experiments on the influence of crops upon weeds, which, if they stand the test of repetition in other countries, deserve to become classical and to find a place in every textbook on Agriculture. But even after reading that quite extensive article, one is left with the feeling that the cultural control of weeds is a sphere in which further experimental investigation is very badly needed, and one in which such research should give most valuable results. It is difficult on reading this paper to avoid the conclusion that some of the observations are most easily explained on the basis of old "soil toxin" theories. It seems almost inexplicable that the classical experiments of Bedford and Pickering in this subject, although widely known since the publication of their book, have not been followed up by later workers.

O. T. F.

* * *

THE TAXONOMY OF *Coffea arabica* L.

A recent publication* of the Agronomical Institute at Campinas, Brazil, will be of great value and interest to botanists working on coffee.

It is a detailed and excellently illustrated description of the varieties and forms of Arabia Coffee to be found in the State of Sao Paulo, including several not previously described. The authors are C. A. Krig, J. E. T. Mendes and Alcides Carvalho and the illustrations are by Jose Pompeu.

The descriptions include notes on origin, tables of measurements of quantitative characters, and chromosome numbers. There is also a key to the 26 varieties and forms included.

The 58 large plates which supplement the Portuguese text will probably be of greater interest to many English readers, as they provide in themselves a reference book which needs no translation. As a rule, habit, leaf characters, flowers, fruit, parchment coffee and beans are depicted for each variety, photographs, line drawings and colour drawings being employed as may be most appropriate in each case. Altogether this is a most commendable contribution to crop taxonomy.

E. E. C.

* Taxonomia de Coffea arabica L. *Boletim Tecnico* n. 62. Instituto Agronomico do Estado de Sao Paulo, 1939.

THE ECOLOGICAL APPROACH TO PROBLEMS OF WEED CONTROL.

[*In a paper entitled "Investigations relating to weed control in Western Canada" in Bulletin 27 of the Imperial Bureau of Pastures and Forage Crops, T. K. Pavlychenko summarizes the organization and nature of work on weed control in Canada, and deals in some detail with studies conducted at the Research Laboratory of Plant Ecology in the University of Saskatchewan. Whilst this work naturally deals with temperate crops growing under relatively dry conditions, some of the findings provoke thought and merit attention by agriculturists in very different climates. It scarcely needs to be pointed out that even in the "wet tropics" there is commonly a dry season in which the factors governing growth of field crops approximate to those of the temperate summer; and furthermore, from the more general viewpoint, the ecological approach to weed problems would appear to be a sound one even under wet season conditions or in perennial crops.*

Some of the significant findings are reviewed under four heads; (1) competition between weed and crop plants, (2) optimum depth of germination of weed and crop seeds in relation to weed control, (3) nature of root systems of various plants, and (4) eradication of perennial weeds. We present here a much abridged version of Pavlychenko's discussion under these headings.—Editor.]

1.—Competition between weed and crop plants.

Heavy versus normal rate of seeding.

In agricultural literature, references are frequently made to "clean" and "weedy" land. In practice, however, there is no such thing as a "weed-free" soil. Careful observations and records obtained at Saskatoon over a period of six years from fields reputed as clean, reasonably clean, and weedy, fully confirm this contention. When these fields were left for one season without cultivation for weed control, all produced heavy stands of volunteer growth, fully sufficient to exhaust completely the available moisture from the soil. For this reason they may all be justly classified as weedy land. When fields with similar infestation were sown to various crops at different rates, and the counts on weed-crop population taken at the early stages of growth, they again appeared as decidedly weedy. Counts taken from the same areas at harvest show at once, however, that certain fields were entirely free of weeds, others contained only a few weeds, while still others were extremely weedy.

Data on the effect of normal and heavy rates of seeding are given in Table I as evidence of the result of competition between weeds and crop plants. Each figure in this table presents an average from sixty sample areas counted in six successive years at Saskatoon, Saskatchewan.

It is evident that the initial percentage population of weed seedlings five days after emergence was considerably less in certain plots because of the heavier rate of seeding (*not due to competition*); that toward maturity, *owing to competition*, the number of weeds was gradually reduced by all crops except flax; and that this reduction was most rapid in (1) barley fields sown heavily, followed in order by (2) barley fields sown at the normal rate, (3) wheat with heavy seeding, (4) wheat at the normal rate, (5) oats with heavy seeding, and (6) oats at the normal rate. A reduction of the weed population did not take place in the case of flax; instead, the numbers of weed plants gradually increased toward maturity.

Amount of dry matter per unit area.

The number of weed plants per unit area, however, is not the best indication of the extent of injury to the crops. Frequently weeds are very numerous at the early seedling stage, but totally disappear during the later part of the season, leaving crops practically free of weeds at harvest. On the other hand, a few luxuriant weed plants in a square foot surviving to maturity may take almost exclusive possession of the land. Therefore the amount of dry matter produced by weeds in relation to that of crop plants per unit area affords a much better criterion of

Table 1.—Effect of normal and heavy rates of seeding on the weediness of different crops.

No. of days from emergence.	Rate of seeding.	Number of plants per square yard.											
		Wheat	Weeds		Oats	Weeds		Barley	Weeds		Flax	Weeds	
			No.	Per cent.		No.	Per cent.		No.	Per cent.		No.	Per cent.
5	Normal	252	118	46.8	224	114	51.3	226	68	30.1	313	140	44.7
	Heavy	424	99	23.3	402	111	27.5	357	36	10.1	411	126	30.7
22	Normal	321	72	22.4	369	88	23.8	341	60	17.6	357	161	47.9
	Heavy	523	54	10.3	457	72	15.7	443	23	5.1	477	143	29.9
40	Normal	332	68	20.4	374	62	16.5	384	33	8.5	223	194	86.9
	Heavy	534	3	.5	461	39	8.4	446	0	0	386	158	40.9
80	Normal	335	54	16.1	376	60	16.1	384	16	4.1	184	238	129.3
	Heavy	534	1	.01	462	36	7.7	446	0	0	282	172	60.9

damage. Data to illustrate this point, obtained from controlled experimental plots, are given in Table 2.

Table 2.—Percentages of dry matter produced by weeds grown in competition with various cereal crops (three-year test).

Competing species	Barley	Spring rye	Wheat	Oats	Flax
Crops	100	100	100	100	100
Wild oats	4	10	77	45	35
Wild mustard	4	39	43	94	443

These are some of the empiric results showing that the same weeds react very differently under similar infestation, climatic and soil conditions when growing with different crops, or if the latter are sown at different rates. The reasons for the variations are not well understood, but they undoubtedly lie chiefly in the biological capacity of the plants to utilize the environment more efficiently, and in their ecological adaptation to the existing soil and climatic conditions.

Readiness and uniformity of germination.

Among other biological characters, readiness and uniformity of seed germination under adverse conditions are important for the success of any plant in competition with other species. These features of germination give the plants an opportunity to occupy the space more rapidly and more completely before other species, with slower and lower rates of germination, appear above the surface in sufficient numbers. During a period of three years, from 1935 to 1937 inclusive, thorough tests have been made under ordinary field conditions to determine the rate of germination of the seeds of twelve common weeds and fourteen cereal crops (Table 3).

Table 3.

Period of test in days.	Percentage germination.	
	12 common weeds.	14 cereal crops.
0 to 5	26.2	73.0
6 to 10	11.2	10.2
11 to 22	10.5	1.6
Total	47.9	84.8

The first line in Table 3 shows that, under similar field conditions, the cereals as a group gave 73 per cent. of the germinated seeds in the first 5 days of the test. Twelve weeds, however, produced only 26.2 per cent. over the same period. During the next 5 days the crops practically reached the limit of their germination capacity, while the weeds continued to germinate slowly until the 22nd day of the test. Due to this fact the crops produced a dense and uniform stand in a few days, thoroughly occupied the soil with their roots, covered the surface with top growth, and left little chance of survival for the weeds which germinated at later dates.

Assimilation leaf surface.

Another biological factor which plays a decided part in determining the competitive efficiency of a species is the extent of the assimilating leaf surface per individual plant at different stages of development. The number of stomata per unit area of the leaf surface accentuates the importance of this character. Plant species which possess a large leaf surface with many stomata per unit area are capable of synthesizing plant building materials at a greater rate, and therefore grow much more rapidly than those with less leaf surface and fewer stomata.

In a comparison between four cereals and five weeds, at the five-day stage, all cereals had much larger leaf surfaces than the weed plants. The numbers of stomata per plant were also much higher in cereals than in weeds, with the single exception of wild mustard. At the blooming stage, on the other hand, all weeds had far surpassed the crops, both in extent of leaf surface and in number of stomata per plant. This certainly gives at least one fundamental reason why weed plants are smothered with ease by a dense growth of cereal crop in the early stage of their development, and why the same weeds, if they survive through this critical stage, choke the crops during the later part of the season.

Plant roots.

A great readiness and uniformity of germination gives any species a definite advantage in competition with other plants of slower and lower rates of germination. This factor becomes of importance before the young seedlings emerge above the surface. The germination itself initiates active growth, but is incapable of supporting it. The assimilating leaf surface, on the other hand, is closely associated with plant nourishment and synthesizing processes, but it assumes this paramount function only after the young plants have emerged and developed a considerable amount of foliage. The root begins to play its part in the life of plants between these two important stages. It is the first organ to support new life developing from the seed. Plants with defective roots die before emerging above the surface. Those with weak root systems live for some time and perish before maturity. Only individuals with healthy and strong roots produce a luxuriant top growth and mature fruit. This statement is based on the most careful analyses of the root systems of many thousands of plants grown under ordinary field conditions, under irrigation, and in the green-house, at Saskatoon.

These quantitative studies of root systems of weed and crop plants indicate that, at least in areas with arid climates, the most severe competition between weed and crop plants centres around the supply of available soil moisture to the plants, this being the limiting factor in crop production. Competition begins as soon as the root system of one plant invades a feeding area of another, and usually takes place long before tops are developed sufficiently to exert a serious competition for light. Therefore, in dry climates roots actually decide the success or failure in competition between species otherwise equally adapted to a region. The top growth is then developed in proportion to the extent of the root system.

The distribution of roots and the depth of their penetration are also important, particularly where two or more unrelated species grow in close association. Some comparative results on the extent of the root systems and yields of barley and wheat, both grown free and in competition with wild oats (*Avena fatua*) and common wild mustard (*Sinapis arvensis*), are given in Table 4.

These data reveal several points of considerable practical significance. First, they show that at the early seedling stage the root systems of the two crops taken from the control and competition plots are nearly equal in size, and much greater than those of the weeds competing with them. Secondly, they demonstrate that as the season progressed, the size of the root systems of crop plants excavated from the competition plots gradually decreased in comparison with the controls. Thirdly these results indicate that crop yields decrease almost exactly in proportion to the degree of reduction of the root systems, due to competition with weeds. Finally, they prove that the weeds which were not smothered by crops at the early seedling stage but reached maturity, often developed more extensive root systems than the crops.

2.—Optimum depth of germination of weed and crop seeds in relation to weed control.

For every species there is a specific depth from which seeds germinate most readily under field conditions. In shallower positions they germinate very unevenly. At greater depth they may refuse to germinate at all unless brought back to the surface by cultivation. This fact has a very important practical significance under the arid climate of Western Canada. If weed seeds are placed at the optimum depth for germination, while crop seeds are buried too deep, a weedy harvest will result, even on land where weed infestation is comparatively light. On the other hand, when crop seeds are placed at an optimum depth, a clean crop may be expected even on weedy land, because cereal crops under such conditions germinate quickly

Table 4.

Age in days after emergence.	Standards.	Length of roots in inches and percentages.				
		Cereal check.	Competition.		Competition.	
			cereal.	wild oats.	cereal.	wild mustard.
Barley 5	inch	112	98	16	99	22
	percentage	100	87	14	88	20
22	inch	5849	4200	752	3814	2850
	percentage	100	72	13	65	49
40	inch	9865	7232	1974	6446	4632
	percentage	100	73	20	65	47
Yield at maturity	percentage	100	85	—	74	—
Wheat 5	inch	68	56	23	57	28
	percentage	100	82	33	84	41
22	inch	3534	2820	1725	2711	4118
	percentage	100	80	49	77	116
40	inch	5342	4169	2046	3449	6053
	percentage	100	78	38	65	117
Yield at maturity	percentage	100	72	—	69	—

and produce dense uniform stands. Weeds, which as a rule develop slowly at the early seedling stage, are at first out-grown, then overtopped, and finally smothered by the crop plants. In dry districts, small-seeded weeds are particularly exacting with respect to the optimum depth of germination. Seeds of Russian thistle (*Salsola kali*), for instance, germinate readily only if placed directly on the ground, or not deeper than 0.5 in. below the surface. Wild mustard (*Sinapis arvensis*), and many others germinate most readily at a depth of from 0.5 to 1 in. below the surface. If buried much deeper, they remain dormant for several seasons. Deep ploughing therefore tends to increase the weed-seed population in the ground. The final result is that, in time, the cultivated layer of soil becomes permeated with weed seeds to such an extent that sufficient are located at the optimum depth for germination irrespective of the method of tillage used for weed control.

This marks the time when the weed problem becomes acute. The situation is almost hopeless if the optimum depth of germination of the weeds in question is disregarded and deep cultivation continues. Shallow surface tillage practised for several seasons, however, destroys most of the viable seeds at the surface, while those located below the depth of cultivation gradually decay and lose their vitality.

3.—Nature of root systems of various plants.

There is at present sufficient experimental evidence to indicate that crops suffer from weeds mainly because the latter utilize the limited supply of soil moisture at the expense of the former. This is particularly true in arid regions such as Western Canada and Central United States. The damage is primarily effected through activities of the root systems. For this reason a clear knowledge of the nature of these organs in different crop and weed plants is essential before any successful method of weed control can be safely recommended.

Root systems of cereal crop plants.

In the course of quantitative root studies at the University of Saskatchewan, it was definitely demonstrated that the root systems of different crop plants vary materially, not only in the amount of roots per plant, but also in their depth of penetration and distribution under the surface. Barley plants, for example, may produce root systems in size equal to or even smaller than those of wheat or oats, yet the root systems of barley will always exert a much greater competitive effect against weeds than those of similar size produced by wheat or oats. This is due to the fact that the barley plants spread the majority of their roots horizontally, and therefore rapidly occupy the inter-row spaces where weeds attempt to establish themselves soon after the crop has emerged. Available moisture in the top layers of soil is quickly depleted by the crop roots, and the weeds, which generally germinate a few days later, rarely develop normally. They persist for some time, but finally most perish. In the meantime the main roots of the crop penetrate deeply and take full advantage of any moisture available in the lower soil strata.

Another important characteristic of the root system of barley is that it consists of from six to thirteen seminal roots against three or less in wild oats, three to four in cultivated oats, four to five in wheat and five to six in spring rye. The seminal roots of spring and winter annual cereal crops were long considered as temporary organs dying off as soon as the crown roots are well developed. For plants in a dry climate at least, this conception is fundamentally wrong. Actually, they not only persist and function throughout the entire life of the plant, but in most years they are its main support from emergence to maturity. It is only in unusually wet years that the crown roots are developed to any appreciable extent to take an active part in supporting the top growth. With this in mind, it is easy to realize the importance for any species of one or several additional seminal roots per plant in its struggle for survival with other plants. The data on this point secured from one hundred random plants of each crop excavated and analysed in different seasons are given in Table 5.

Table 5.

Average number of seminal roots per plant.

Wild oats	Banner oats	Marquis wheat	Prolific spring rye	Hannchen barley
3	3.5	4.4	5.6	6.3

The root systems of spring rye, wheat and oats, unlike that of barley, have a more sloping penetration. Spring rye most closely resembles barley in this respect. Spring wheat takes an intermediate position, and oats the opposite extreme in this series. It is interesting to observe at this point that barley ranks as the most efficient competitor of weeds, followed successively by spring rye, wheat, and oats, irrespective of the basis upon which evaluation is made.

Root systems of perennial weeds.

Weeds such as perennial sow thistle (*Sonchus arvensis*), Canada thistle (*Cirsium arvense*), field bindweed (*Convolvulus arvensis*), poverty weed (*Iva axillaris*), leafy spurge (*Euphorbia esula*), &c., constitute a separate group with respect to the nature of their root systems. Their perennial roots serve not only as organs for the absorption of soil moisture and nutrients, but also for the storage of food reserves and as a means of vegetative propagation. For these reasons, their eradication is not possible without complete destruction of their subterranean parts. In this connexion, a knowledge of the morphological features, anatomical structure, and mode of penetration and distribution of their root systems is highly desirable. The kind of results obtained in a study of these features at Saskatoon which has furnished information of considerable practical interest may be exemplified as follows:

Perennial sow thistle distributes its roots mostly within the first six inches below the surface.

The vertical roots penetrate freely to a depth of six feet. Both the horizontal and vertical roots may be from 1 to 7 mm. in diameter. They are very succulent and covered with a thin and weak bark; these facts constitute a basis for successful eradication in one season. By applying a shallow, but thorough surface tillage and preventing top shoots appearing above the surface for a period of from ten to twelve weeks, the food reserves stored in the roots are depleted, and the roots themselves are weakened. In this condition the thin epidermis affords the roots little protection against decomposition and they decay very rapidly.

Quack grass (*Agropyron repens*) is another principal perennial weed in Western Canada. Its persistency is due to the presence of long stolons with numerous vegetative buds and a multitude of fibrous roots. Fortunately this weed may also be eradicated completely in one season by shallow surface cultivation, which totally prohibits top growth for fourteen to sixteen weeks.

The roots of poverty weed, field bindweed, hoary cress, and leafy spurge possess an extremely thick corky layer in their bark, abundant food reserves, and penetrate to a depth of 12 to 20 feet below the surface. For these reasons they may resist successfully a complete inhibition of their top growth for a period of one season without noticeable loss of vigour. In the second consecutive year of this treatment, they suffer noticeably, but often preserve some of their vitality even after three years. In small patches, these and other perennial weeds may be completely eradicated in one season by chemical treatment.

4.—Eradication of perennial weeds.

The most serious perennial weeds in Western Canada propagate both by seed and by subterranean roots. The young plants originating from the seeds possess no perennial root stalks for several weeks, remain small, and, unlike the annual weeds, seldom produce seed in the first year of growth. For this reason they are easily destroyed by cultivation during the early stages of growth. However, as soon as these seedlings develop perennial roots their destruction becomes extremely difficult. Any small section of a perennial root is capable of re-growth, and of establishing a new patch. Therefore, *a hundred per cent. kill or complete eradication of both top growth and perennial roots must be the ultimate goal in every case.* This may be easily obtained in small patches by chemical treatments.

The eradication of perennial weeds by chemicals on a large scale, however, is impracticable, as the cost is prohibitive. Fortunately eradication in many cases can be accomplished satisfactorily by cultural methods. A shallow, yet thorough black summer-fallow proved to be fully effective in the case of perennial sow thistle, quack grass and Canada thistle. The emphasis must be placed on "shallow" cultivation, as deep cultivation does not add materially to the effectiveness of the treatment, and is slow and expensive. As in the case of chemicals, the extent of direct mechanical injury to the plants is not important, but it is necessary to prevent completely all shoots from appearing above the surface for a definite length of time.

E. E. C.

OBITUARY.

Mr. GEORGE MOODY STUART, C.B.E.

It is with great regret that we have to announce the death on the 30th May at High Wycombe of Mr. George Moody Stuart who had, ever since the inception of the Imperial College of Tropical Agriculture, been a member of its Governing Body and Chairman of its Finance Committee.

Mr. Moody Stuart was a leading figure in the British Colonial sugar industry with which he first became connected in 1882 when he entered the firm of Henckell Du Buisson & Co., the West India Merchants. He was one of the earliest to realize the need for developing the central factory system in the British West Indies, his first venture in this direction being in Antigua where, with the co-operation of the late Sir Francis Watts and the help of a Government grant-in-aid amounting to just under half of the capital required, he established the Gunthorpe's Central factory. This factory was, after the Usine Ste. Madeleine in Trinidad, the oldest Central in the British West Indies. It was soon followed in St. Kitts by the Basseterre Central, privately capitalized without Government aid. Two years later Mr. Moody Stuart's firm was able to take over the Usine Ste. Madeleine from the liquidators of the New Colonial Company and thereafter managed some of the most successful sugar factories in the West Indies.

Mr. Moody Stuart played a prominent part in the foundation of the Imperial College of Tropical Agriculture in whose progress he always showed very keen interest. Although Sir Norman Lamont was the first to call attention to the need for an agricultural College situated in the tropics, it was Mr. Moody Stuart who in 1920, at a meeting of the Agricultural Society of Trinidad and Tobago, urged the Governor to take up this matter with Lord Milner, the then Secretary of State for the Colonies, and who asked that export duties on agricultural products be imposed to raise funds for the establishment of such an institution. The resolution, seconded by Sir Norman Lamont, was carried unanimously and, soon after, the College was born.

The Governing Body recorded their appreciation of the eminent services which Mr. Moody Stuart rendered to the College by passing the following resolution which was moved by Mr. Eric Macfadyen "That the Governing body hereby record the sorrow with which they learnt of the death on May 30th of their colleague Mr. George Moody Stuart, C.B.E., one of the pioneers of the movement which led to the foundation of the College, and their appreciation of his services as Chairman of the Finance Committee for twenty years, and that they desire to convey to his family their condolence in the loss which they have sustained."

LIVESTOCK IMPROVEMENT IN JAMAICA IN WAR TIME.

J. W. Howe, Dip. Agric., B.S.A., M.Sc.
(*Live Stock Officer, Jamaica.*)

The Live Stock Industry is an important branch of agriculture in Jamaica, and all classes of live stock are raised in comparatively large numbers. While some attention has been paid to the improvement of live stock, the general type of animal raised at present leaves much to be desired, as the breeding of most classes of live stock is mixed.

Although all classes of live stock can be raised in the Island, the imports of live stock products into Jamaica assumed large proportions. It was realized that, with the outbreak of war, there was a strong possibility of these imports being restricted, and it would therefore be necessary to increase the volume of live stock products available locally. A Food Production Board was accordingly set up to extend both food and live stock production and a Live Stock Division organized, for the purpose of both increasing and improving live stock.

To determine what action might best be taken in bringing about such improvement, a survey of the live stock population was undertaken throughout the Island, and information was obtained as to the areas in which the live stock population was concentrated. Such a survey provided information as to the number and class of live stock in the various areas, the availability of feed, and the extent to which the products could be marketed locally. The survey was undertaken by the Staff of the Live Stock Division with the assistance of the Jamaica Agricultural Society and the Field Officers of the Department of Agriculture, and when completed, presented a more or less accurate picture of the live stock situation at the end of 1939.

It was found that the conditions under which all classes of live stock were raised, and the type of animal which was being raised could be greatly improved. It was decided that the best means of improving such animals would be to establish a number of Live Stock Improvement Centres at which well bred good types of sires would be available for use of the public. Thus it would be possible to grade up the live stock in the district. The method of making such sires available is through (1) Live Stock Improvement Centres, and (2) subsidizing approved sires for public service.

A Live Stock Improvement Centre is located in an area where there is already a sufficient live stock population to warrant placing sires in that district for service. The Centre varies in size from two acres, in areas where there is heavy rainfall and plenty of feed, to eight acres in some of the dry areas where feed is scarce during a considerable part of the year. The area is fenced and is divided into paddocks for the animals, with a bull stall and feed room, together with a service paddock located near the centre of the area. There are at least two paddocks for the bull, two for the goat and two for the boar, which makes it possible to rest the pastures, maintain good feed conditions and reduce parasites. Each Live Stock Improvement Centre is in charge of a caretaker, who looks after the animals, plants what fodder crops are necessary, and admits the animals brought by the public for service.

As no provision is made to pasture animals any length of time, persons wanting to take advantage of the services of the sires, are instructed to bring the females for service while they are on "heat". This has caused some difficulty, as many of the small farmers do not realize that female animals will only take service during the "heat period", and it has been found necessary to stress this point to the people who intend bringing their animals for service. The animals are allowed to remain at the Centre for a period of 24 hours. There are no service fees. When an animal has been served the caretaker issues a service certificate, giving the description of the animal, and the sire by which the animal was served. It is expected that by such certificates, the public will not only have a more definite record of the breeding of the progeny, but will be encouraged to take an interest in the production of a better class of live stock than hitherto. It is proposed to hold shows at each of the Live Stock Improvement Centres, in which will be entered progeny sired by the animals standing for service at that Live Stock Improvement Centre.

Feed is supplied to all Centres, and at each a plot of ground is cultivated and planted under food crops for the live stock at the Centre. In this way it is possible not only to reduce the costs of feeding, but also to encourage the farmers of the district to grow the right type of feed for their animals.

The Live Stock Improvement Centres are also used to disseminate information to farmers regarding the proper methods of breeding, feeding and management of their live stock. Although the Centres have been in operation only a few months, a noticeable increase in interest is already evident on the part of the farmers who have live stock in the district in which a Centre is located. It is not possible to have sufficient Centres to provide services for all persons raising live stock and the Centres have been located only in areas where there is already a large live stock population. In areas where the live stock population is insufficient to warrant establishing a Centre, it is proposed to ask private individuals who have approved types of sires to allow such sires to stand for public service. The person allowing his animal or animals to stand for service will be paid for each service given. In this way, services are available to the public without charge in areas where there is not sufficient live stock to warrant the establishment of a fully stocked Live Stock Improvement Centre.

The type of sires used at the Live Stock Improvement Centres depends on the type raised in the district, but in the case of cattle at most of the Centres bulls of the dairy type have been stationed. The breeds used are Sahiwal-Jersey, Sahiwal-Guernsey and in a few cases purebred Jerseys and Guernseys. The recent establishment of a Condensary in the Island has done much to increase the interest taken in dairying, and the dairy bulls stationed for service should improve the type and production of dairy cattle.

In the case of pigs the Berkshire breed is used, as this type does well in Jamaica and during the last ten years has become well established. The Berkshire breed in not the extreme of either the bacon type or the lard type. The extreme lard type such as the Polan China or the Duroc Jersey tend to get much too fat under our conditions.

Goats are raised in Jamaica in large numbers but little has been done to improve the type of animal. Scant attention has been given to the production of a milk type of goat, and at present most of the goats are raised for meat. To improve milk production and thereby provide a supply of fresh milk for the small farmer, rams of either the Toggenburg or the Anglo-Nubian breed have been selected for the Live Stock Improvement Centres. The Department has also imported a number of pure bred goats, of the breeds mentioned, from the United States. Such animals will provide rams as sires for the Live Stock Improvement Centres.

The beef cattle industry is mainly in the hands of large penkeepers, and improvement of the type of beef animal raised is being undertaken through them. It is expected that work on improvement of beef cattle as well as improvement in conditions of marketing beef, will be undertaken.

The question of improved fodder and pasture conditions is also being considered as there are few grasses which can be used throughout the year for feeding stock. A number of varieties of grasses and fodder crops have been received from other tropical countries, and are at present being tested with a view to establishing the more promising varieties in the Island. The main concentrated feeds used are coconut meal and corn hominy meal, a by-product of the corn meal factory recently established here.

Live stock in Jamaica is an important branch of agriculture, and its expansion will do much to provide a more stable type of agriculture than hitherto. The plan of improvement through the system of Live Stock Improvement Centres and subsidized sires will, it is expected, do much to increase the production of live stock and make the Island more self-supporting, as well as improve the type of stock raised and thereby provide the live stock farmer with a greater return for his efforts.

THE ACTIVITY OF PLANT-GROWTH HORMONES.*

SUBSTANCES which stimulate the vital processes of plants—materials variously known as growth-hormones, growth-regulators, auxins, phyto-hormones and growth-substances — are now receiving wide study, and some outstanding results have already been obtained. Thus beet seeds soaked in a solution of hetero-auxin (indole-3-acetic acid) have been found to give an increase of 157 per cent. in the weight of the harvested beets, an increase of 129 per cent. in the weight of the leaves, and an increase in the absolute sugar yield of 123 per cent. Some grasses, treated with Vitamin B1, have been found to yield seven times as much dry weight as controls.

In discussing physiologically-active materials, two groups of substances have to be considered, namely, (1) substances which are naturally produced within the plant, called phyto-hormones, (2) extraneous foreign substances, not naturally produced within the plant, which possess the ability to alter the rate or direction of metabolic processes. With regard to the first group, it may be noted that the phyto-hormones, like the vitamins and hormones of animals, exert a catalytic effect on the life and growth of plants. Moreover, just as in animals, the presence or absence of hormones may cause profound modification in development and behaviour, so also the phyto-hormones exert a controlling influence on the behaviour of plants. The downward growth of roots, the formation of roots, not only at the base of a plant but also on cuttings, and the elongation of seedlings in the dark, are some of the characteristic effects by which the presence of phyto-hormones are recognised.

The growth and development of plants are dependent on the action of certain chemical substances. On the one hand are the ordinary plant nutrients, such as certain inorganic salts, water and carbon dioxide, which the plants take from their underground and aboveground surroundings; on the other, are substances which stimulate the vital activities of the plants, namely, the growth hormones, whose effects are quite distinct from those produced by the ordinary plant nutrients embodied in the usual manures and fertilizers. It seems that some varieties of plants are deficient in their content of growth

* The information on which this account is based was drawn from the following three papers:

(1) Plant Hormones, by D. H. Killeffer (*I.E.C.*, News Edition, Vol. XVIII, No. 9, p. 395).

(2) A New Way of Stimulating Beet Plants, by H. V. Amlong and G. Naundorf. (Abstract in *Facts About Sugar*, Vol. XXXV, No. 3, p. 35).

(3) Notes on "Growth Promoting Substances," by P. H. Carpenter. (Tocklai Experimental Station, *Memorandum* No. 9, November, 1939).

hormones, and that this deficiency may be artificially supplied. By the use of hormones (which have, among other effects, the property of increasing the germinating power of inferior seed), it appears that a way is opened up to compensate for a lack of vital vigour in plants. Data available indicate that certain of the vitamins are formed in plants and utilized by them to promote and control growth. All root systems so far investigated require Vitamin B1, which may thus be tentatively considered as the specific plant root vitamin. The formation of Vitamin B1 in the plant is dependent on the effect of sunlight on its leaves, and consequently it can be considered a true hormone, since it must be formed in one part of the plant and transmitted to another to be effective. Because Vitamin B1 has been synthesised, and may be obtained in a pure form uncontaminated by extraneous materials, experiments on its effects on plant life have given clear and definite results. For instance, by isolating tips of roots alone in nutrient solutions containing the essential mineral salts, sucrose, nitrate-nitrogen, and as little as one part in 10,000,000 of Vitamin B1, flax roots can be grown in vitro at the rate of approximately an inch a day indefinitely. In comparative growth experiments made in nutrient solutions with and without the addition of Vitamin B1, some grasses were found to yield seven times as much dry weight as controls when treated with so small an amount as one part in 100,000,000. In the concentration of one part to 10,000,000,000 parts of nutrient solution, Vitamin B1 may cause a detectable increase in the yield and vigour of certain plants.

Ordinary organic manures (stable manure and the like) are believed to supply vitamins to the soil. It is a curious fact that, while isolated roots appear to be universally dependent upon supplies of Vitamin B1 and other vitamins for their prolific growth, many, if not all, of the great economic crops (notably corn, wheat and tomatoes) are not particularly benefited by the addition of an excess of Vitamin B1 to the soil in which they are grown. The explanation is that these plants, probably through the long processes of selection by agriculturists, have capacities for producing their own vitamins in quantities sufficient for their needs.

With regard to the extraneous foreign substances which possess the power of altering the rate or direction of metabolic processes, it has been found that they include an amazing number of apparently quite unrelated compounds of the widest chemical dissimilarity, ranging from such simple compounds as carbon monoxide and ethylene to complex alkyl-aryl derivatives having multimembered ring systems in their structures. Physically, these physiologically-potent compounds may act in the solid, liquid and gaseous states in dilutions as low as a fraction of a part per million. The examples cited below typify the changes that can be induced in plants by suitable application of these extraneous compounds.

Experiments with ethylene in the atmosphere around plants have shown that concentrations so dilute as to be almost undetectable by other means, affected the rate of cell growth in a peculiar and specific manner. Leaves of tomato plants, for instance, developed a tendency to grow downward instead of upward. Apparently the cause of this downward curling of leaves is a differential in the rate of growth between the upper and lower sides of the leaves. Certain processes in fruits are also stimulated by ethylene. Thus, the colouring of oranges by ethylene has been widely practised, and ethylene also affects the dormancy of the buds of potatoes and other vegetables, permitting control of the rest period between maturity and new growth.

As recently as May, 1936, were harvested the first fruits (of a tomato plant) developed by direct chemical stimulation of the ovaries of flowers as distinct from natural or artificial pollination. The tomatoes thus grown were seedless, but otherwise normal. The method consisted in removing the stamens from the flowers and treating their cut pistils with a one per cent. mixture of indole-propionic acid and lanolin. Other fruits and vegetables have been produced without seeds by similar technique. The reagents used have included derivatives of acetic, propionic and butyric acids, phenylacetic acid, pyrrole carboxylic and acetic acids and naphthalene-acetic acid, as well as their salts. These substances have been applied in solution in lanolin (wool fat), in concentrations varying from 0.5 to 5 per cent., and as aqueous solutions as dilute as one part of reagent in a million parts of water.

Roots have been induced to grow on leaves, stems, and even flowers by the proper application of a chemical stimulant. Far more practical is the stimulation of the rooting of cuttings for purposes of propagation. Minute doses of several physiologically-active compounds, notably indole-acetic and indole-butyric acids, may cause the rooting of cuttings of difficultly-rooted species, and may greatly accelerate the rooting of easily-rooted varieties. Actually, the stimulant promotes the acceleration of cell growth, producing first a protuberant swelling. From this swelling, roots may then grow. Numerous compounds induce this response, but none has been found to be specific for any particular response.

The remarkable fact about extraneous substances which catalyze plant processes is the similarity of the actions of totally different chemical compounds. For instance, control of the period of dormancy of potato buds can be accomplished by the relatively simple gaseous hydrocarbon, ethylene (C_2H_4), in very much the same way as it can be produced with the complex alkyl-aryl acid, indole-butyric acid ($C_{12}H_{22}O_2N$). Indeed, so similar are the activities of many different chemical individuals that it has so far been practically impossible to determine with any great certainty just how chemical constitution is related to physiological activity. Moreover, no satisfactory differentiation

has yet been made between the actions of true hormones formed in the plants themselves and foreign substances which induce similar responses. Extraneous agents may stimulate and promote the formation of active hormones in and by the plant itself, and may thus produce reactions identical with those produced by the hormones. The question of the precise identities of the hormones consequently is seriously complicated.

Although much remains to be learned about these physiologically-active substances and their effects on plants, it is interesting to speculate, even at the present stage, on the possible bearing of these substances on the question of obtaining high-yielding varieties of crop plants. At present, plant breeders, for instance, need to initiate a long and expensive process of selection for the purpose of breeding new varieties, and, in the course of several years, may obtain a strain that will yield a few hundred pounds more per acre; in other words, by selection, they produce seed having more vital vigour, which may mean that they contain more growth hormones. If the process of soaking seed in a hormone solution to obtain a more than doubled yield becomes a reality, the breeders and geneticists will be spared a lot of trouble.

H. F. B.

BORON IN AGRICULTURAL AND HORTICULTURAL PRACTICE.*

During the past year, some three hundred and fifty papers and articles relating to the uses of boron compounds in agriculture and horticulture were published in twenty-one different countries. Nearly half of these contributions were made in the United States, where the rapidly growing interest in the subject was particularly marked. According to a recent report, boron investigations covering a wide range of soils and crops are now in progress in at least twenty-six American States. Important among the new findings published in the United States during the year was the efficacy of applications of boron to the soil in controlling "canker" disease, also termed "girdle" or "internal black spot," of table or canning beet. The disorder appears to be closely related to "heart-rot", the well-known boron deficiency disease of sugar beet and mangolds. Canker is said to be very prevalent and of considerable economic importance in the canning beet-growing districts in the States of New York, Michigan, Oregon and Wisconsin. Its presence has also been observed in Washington State.

The beneficial use of boron on daffodils was reported from North Carolina, and further advance was made in New York State in the study of internal bark necrosis of apple trees and its control by the application of boron. A first progress report on "drought spot" of prunes was also issued in the latter state. The first recorded instance of boron deficiency in cabbage and related crops, under field conditions, was reported from Wisconsin. The disorder, an internal breakdown of the stem in the region of the core, was largely controlled by the application of boron. In Florida, the condition of citrus trees in several groves is considered to suggest a lack of boron. An investigation of this possibility has been begun. An apparently new disorder of tomato plants, experienced in New Jersey, and characterized by a form of yellowing of the leaves, was controlled by suitable applications of boron. In the same State, the first recorded symptoms of boron deficiency in roses grown in sand cultures were described.

Three important reviews of literature were published in the United States during the year. The first supplement to the American Potash Institute's Bibliography of literature "Boron as a Plant Nutrient" was issued in May and listed 171 papers reviewed during the period July to December, 1938. The Chilean Nitrate Educational Bureau Inc., New York, published the third edition of its well-known "Bibliography of References to Literature on the Minor Elements". This lists 449 papers relating to boron. A booklet entitled "Boron in Agriculture", published by the Pacific Coast Borax Company, New York, presents a concise and well-illustrated review of work conducted in the United States and Canada.

In New Zealand and Australia, the list of crops which may suffer from boron deficiency under field conditions was also extended. In the former country, workers at the Cawthron Institute found that a disorder of apricot fruits, which is sometimes prevalent in the orchards there, is due to lack of boron, and can be controlled by the addition of boron to the soil or by spraying it on to the tree. The disorder in question has been termed "brown spotting". Further investigation of the subject is in progress. In Queensland, Australia, a condition of young pineapple plants, known as "crookneck" (so called on account of the manner in which the heart leaves are twisted) was largely controlled by spraying the plants with boron. Progress was reported from New South Wales concerning the investigations being conducted there on "needle fusion" of pines. The application of boron to diseased trees has given complete or partial recovery in some cases, but in others it has so far been without result. This disorder of pines also received further attention in Great Britain, where it was shown that the leaves of affected trees contained consistently less boron than did those of healthy trees. The results of additional investigations concerning the control of "brown heart" of swedes in New Zealand by the use of boron were reported. It was stated, too, that the use of boron for the control of cork

* Reprinted from *Nature*, Vol. CXLV, No 3681, pp. 766-767, 1940.

disorders of apples in New Zealand is likely to have wide application in the Alexandra district of Central Otago.

Other notable contributions came from the Dutch East Indies and Holland. The symptoms of boron deficiency in coffee have been studied at the Besoeki Experiment Station in Java, and similar investigations on potatoes under both laboratory and field conditions were carried out in Holland. French workers extended their investigations to a study of the boron content of various types of soil, and have published their first results. Work in Canada related to swedes and turnips more particularly, and the use of boron there on additional crops is now being studied.

The Institute for Tobacco Research of the German Reich has investigated the essential nature of boron for the healthy growth of tobacco. As a result, boron has been applied to its tobacco fields for some years, with good results. The well-known German worker, Brandenburg, published early in the year a review in German of available information concerning the use of boron in plant nutrition, with special reference to his own investigations. It was also reported from Germany that the production of borated superphosphate for use on the sugar beet crop in 1938 was 30,000 tons, compared with 20,000 tons in 1937. Another noteworthy feature was the publication by several workers in the United States, in Germany and in Great Britain of methods relating to the determination of boron in soils, plants and fertilizer materials. Important developments, in addition to those already mentioned, took place in the British Isles. Further successful results relating to the control of " brown heart " in swedes and turnips by the use of boron were reported from Northern Ireland, the north-east of Scotland, and the north-west of England, in experiments carried out in 1938. These were the first investigations in the areas concerned. The disease was also reported to have been prevalent in Devon and Cornwall. In an experiment in Scotland in 1938, boron (applied as " Boronite ") gave a large measure of control of internal rust spot of potatoes. Special mention must also be made of the publication early in the year, of the third of the reviews " Boron and Plant Life " (*Fert. Feed. J.*, February-April, 1939). This review, written by A. C. and R. W. G. Dennis, summarized developments reported in some two hundred papers during the latter half of 1937 and in 1938. The article was later published in French.

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Phosphates and Phosphate Fixation.*

The exceptional immobility of, and the powerful fixative capacity of clay for, both natural and added phosphates in soil have led some workers to conclude that plants derive much of their phosphate requirements from organic compounds. Estimates of the proportion of total soil phosphate present in organic combination vary widely, but are often of the order 50 to 80 per cent. The observation that additions of nucleic acid to nutrient solutions stimulated plant growth, causing simultaneous disappearance of the nucleic acid, suggested that plants might be able to utilise phosphorus in this form, either directly or indirectly after hydrolysis. Using an improved procedure for separating nucleic acid material from soil, certain Canadian investigators have obtained up to 65 per cent. of the apparent organic phosphorus in the nucleic acid fraction. It has been shown that humic acid increases the solubility of several different phosphates up to a certain limit represented by the dissolution of 600 to 1,000 mg. of organic matter per litre, and it has been estimated that about 80 per cent. of the total phosphorus in acid soils could occur in organic form, mainly as esters derived from plants and decomposable by bacteria. Liming facilitates bacterial conversion into an inorganic form, and in calcareous soils little or no organic phosphorus persists. Thus, it has been found that, on the coastal-plain soils of Virginia, organic matter reduces phosphate fixation. Green-manure crops also increase phosphate availability. The ratio of available to total phosphoric acid has been found to fall with increasing contents of organic matter and colloids, but to be practically unaffected by calcium carbonate content.

The degree of fixation of glycerophosphate (a simple form of organic-phosphate) varies greatly with the nature of the soil. In a highly colloidal Cecil soil, fixation has been proved to be rapid and complete; in two other (Norfolk and Las Vegas) soils, fixation is gradual, about four weeks being required to fix 70 per cent. of the added phosphate. After sterilisation, however, very little fixation occurred, suggesting that, in these soils, microbial decomposition of organic phosphates to an inorganic form is the first stage in fixation.

A method for determining organic phosphorus in soils has been described; it is based on the liberation of the phosphorus by decomposing the organic matter with hydrogen peroxide and subsequent extraction with 0.2 N-sulphuric acid. Magnesium ions are so firmly bound to silicates that they play no part in phosphate fixation, unless at exceptionally high pH values. Three forms of phosphate fixation are distinguished: (1) colloid fixation, when the PO_4 group occurs as a structural unit in the colloidal aggregate; (2) "saloid" fixation, when the group H_2PO_4 occurs in the ion swarm which surrounds the positively-charged ion complex on the acid side

* From *Reports of the Progress of Applied Chemistry*, Society of Chemical Industry, England, Volume XXIV, 1939, Section on Soils and Fertilisers by G. V. Jacks. The references to literature have been omitted.

of the isoelectric point. These two forms may be termed "micellar" fixation to distinguish them from (3) "extra-micellar" fixation, when the PO_4 group is bound by calcium or other cation with which it forms insoluble compounds.

By extracting soil with caustic soda, followed by an acid, the phosphorus compounds of the soil have been fractionated into three broad groups: (1) organic compounds soluble in alkali; (2) inorganic compounds dissolved by extraction with alkali followed by an acid; (3) insoluble compounds. The largest fraction of total soil phosphorus was insoluble. The fact that in some of the soils studied, over 50 years of fertilising had not changed the amount of this fraction, indicates its inertness in the phosphate cycle. Phosphorus added to acid soils tends to accumulate in alkali-soluble forms, that added to neutral or alkaline soils, in acid-soluble but alkaline-insoluble forms. It has also been found that exchangeable calcium causes a marked depression in the solubility of soil phosphorus in sodium hydroxide. Caustic soda solutions may extract 90 per cent. of the total phosphorus of acid soil, but considerably less if calcium carbonate is present. A sensitive method of determining soil phosphates has been described, involving the application of a photo-electric colorimeter to the ceruleo-molybdate reaction. The determination differentiates phosphates from other forms of phosphorus, and is not affected by the colour of soil organic matter.

* * *

Biochemical Approach to Grass Problems.

In an article to the *Journal of the American Society of Agronomy*, 31, No. 9. 751-60. 1939, A. G. Norman, formerly of Rothamsted Experimental Station and now Professor of Soils, Iowa Agricultural Experiment Station, Ames, Iowa, U.S.A., raises a number of points of wide interest and application.

Norman states that in its biochemical aspects, as in others, the pasture problem is a peculiarly complex one. Much of the biochemical work on forage crops in recent years has been concerned quantitatively with minor constituents, such as the mineral constituents, carotene, and the vitamins, and lately also with essential amino-acids. "There seems to be a regrettable tendency in considering the quality of grass to look chiefly at the nitrogen content and to imply that young grass is so much better than mature hay simply because of the higher content of protein it contains. Beasts do not live by protein alone, and even in the best grass the protein is a relatively small part of the whole. There appears then to be a real need for a further study of the energy-supplying constituents, which together comprise by far the greatest proportion of feeds, an examination of their relative availabilities, the prediction of their digestibility, and the study of management practices that will maintain a profitable compromise between yield and quality. This means that it will be necessary first to break down some of the complex pasture problems into simpler units which may separately appear not to be very practical, but which taken together should give what is wanted. The changing composition of the plant with age, the effect of fertilizers, and management, all ought to be determined independently first".

A strong case is made out for the direct determination of cellulose and lignin as a minimum requirement in studies of pasture herbage composition. "In addition it would be desirable that an attempt should be made to separate the other major carbohydrates, both structural and reserve, in order that the percentage of material unaccounted for shall be as small as possible, and not a composite of errors in method and technique as at present".

Certain experiments made at Rothamsted on the changing composition of grasses with age and fertilizer treatment are quoted to illustrate the use of these newer analytical procedures and the breakdown of the pasture problem into the equivalent of pure cultural studies.

"Arising out of the data presented, the following points seem to call for attention and to be capable of solution by an extension of the direct methods of determination just described:

"First, what is the nature of the primary and secondary carbohydrate metabolism of grasses? Is fructosan a major temporary reserve only in ryegrass, or is it to be found generally in many species? What relationship, if any, is there between fructosan formation and storage and the rapidity of new growth following cutting or grazing? Are there other reserve carbohydrates as yet unidentified?

"Second, what is the influence of lignification or lignin deposition on the digestibility of herbage? Are the advantages of feeding young grass so exclusively confined to the higher protein content and greater digestibility of the cellulose as has been supposed, or may not the replacement of much soluble polysaccharide by insoluble structural constituents be also concerned?

"Third, what is the nature of the hemicelluloses of grasses? How may they be determined, and what rôle, if any, do they play in affecting the value of the herbage? Can they act as reserves, as has sometimes been asserted, or should they properly be regarded as structural constituents and consequently out of circulation so far as renewal of growth after cutting is concerned? Because of limits of time, this group has not been discussed, but it should perhaps be stated that in all the samples mentioned, the hemicelluloses were probably quantitatively more important than the lignin.

"This list of questions could be considerably extended, particularly if the nitrogenous constituents are also included. Most of the questions are quite fundamental to a fuller understanding of grasses and the proper management of grassland. Their solution depends on the further development of biochemical methods in this field and the abandonment of empirical procedures as research tools".—(*Herbage Reviews*, Vol. VIII, No. 1, pp. 13-14, Review by R. O. Whyte. 1940.)